

Nanomaterials-Based Electrodes for Energy Storage Devices with Fast Rate Capabilities

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Acknowledgments

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US DOE Small Business Innovative Research (SBIR)
DOE 2002 Project**

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Nanopowder Enterprises Inc.

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NEI Markets

-Nano enables the application of-

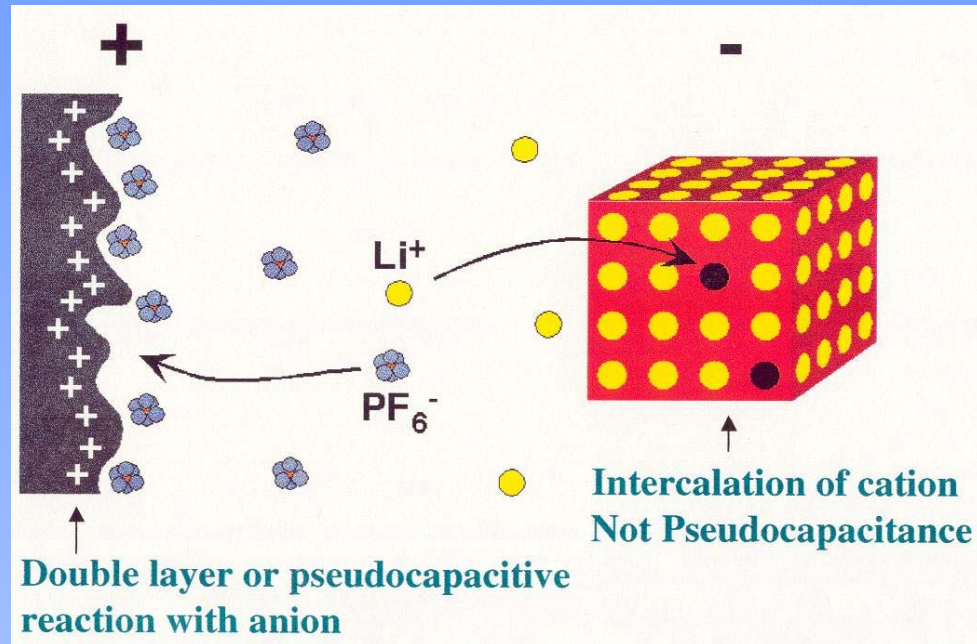
- **Polymer Nanocomposites: coatings and bulk**
 - **Nanoparticles for Drug Delivery**
 - **Nanoparticle laden fluids**
 - **Specialty Nanopowders**
 - **Rechargeable Batteries**

High Rate Energy Storage Devices

Goals of the Program

- **Develop nanostructured anodes for a new type of high rate energy storage device called Asymmetric Hybrid Cell**
- **Fabricate prototype Asymmetric Hybrid Cell with following features-**
 - Capable of working efficiently over a wide temperature range (-30°C to 70°C)
 - Long cycle life (> 100,000 cycles)
 - Power density as good as that of a supercapacitor
 - Energy density comparable to, or higher than, that of Pb-acid batteries
 - Fast rate of charge (complete charge in 1 min.)

Concept of High Rate Asymmetric Hybrid Cell



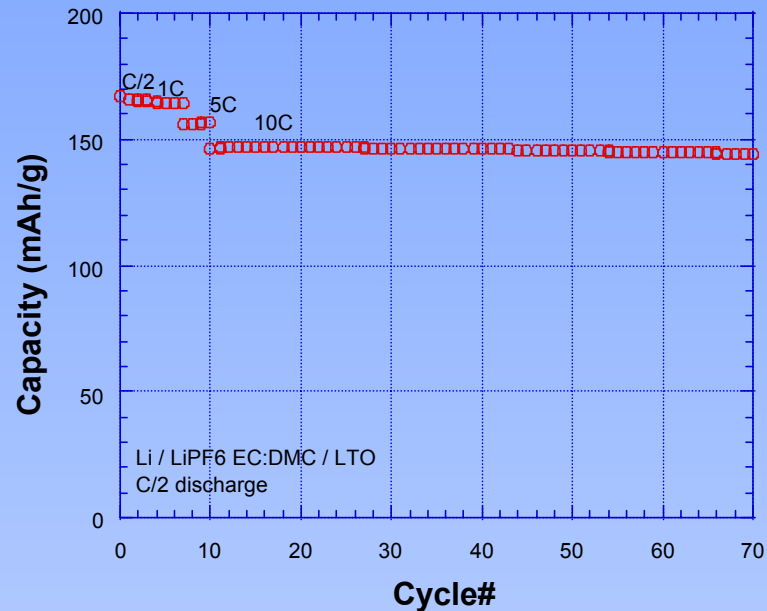
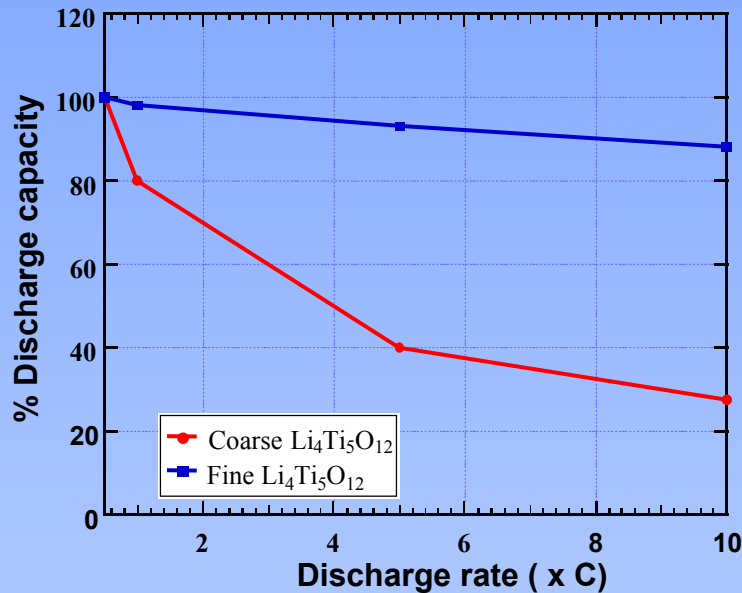
Courtesy Telcordia Technologies

A thin, flexible, highly manufacturable and non-aqueous plastic laminar device

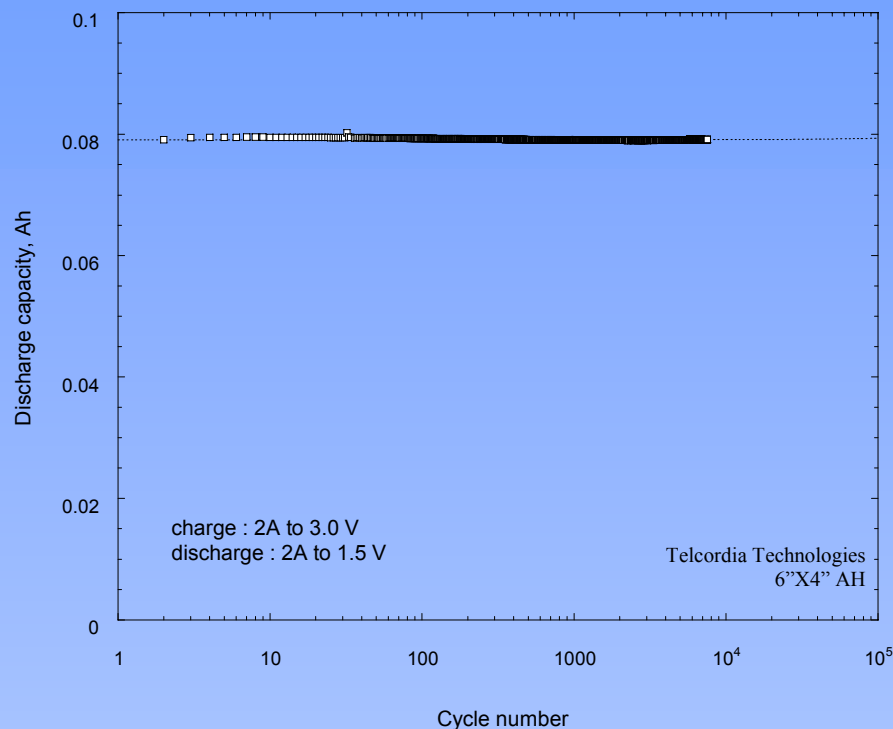
Reference: Amatucci et al., *Journal of The Electrochemical Society*, **148** (8), A930 (2001)

Ultrafine Electrodes Exhibit Faster Rate Capabilities

- $\text{Li}_4\text{Ti}_5\text{O}_{12}$ Electrodes -



Long Cycle Life of Prototype Hybrid Cells

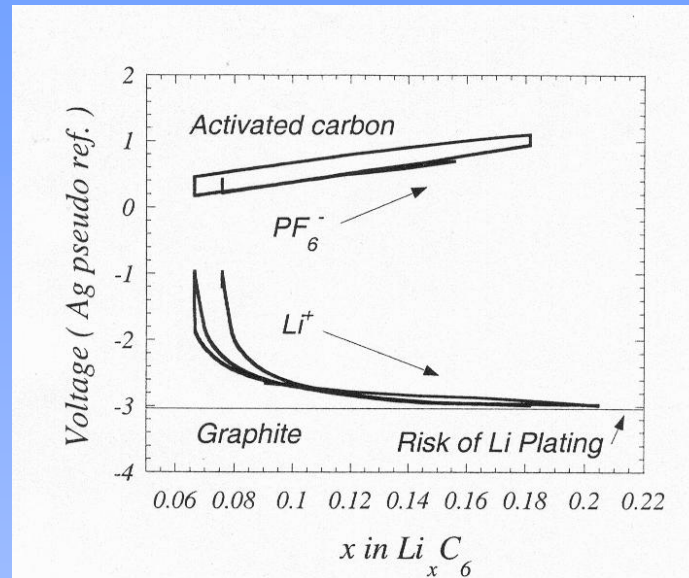


Cathode: High surface area activated carbon (700 – 2000 m²/g)

Anode: Ultrafine Li₄Ti₅O₁₂; Electrolyte: 1M LiPF₆ in 2:1 volume ratio of ethylene carbonate: dimethyl carbonate

Dimensions: 6'' X 4'' (Courtesy Telcordia Technologies)

Rationale for Lithium Intercalating Anode Materials



Courtesy Telcordia Technologies

Intercalation voltage

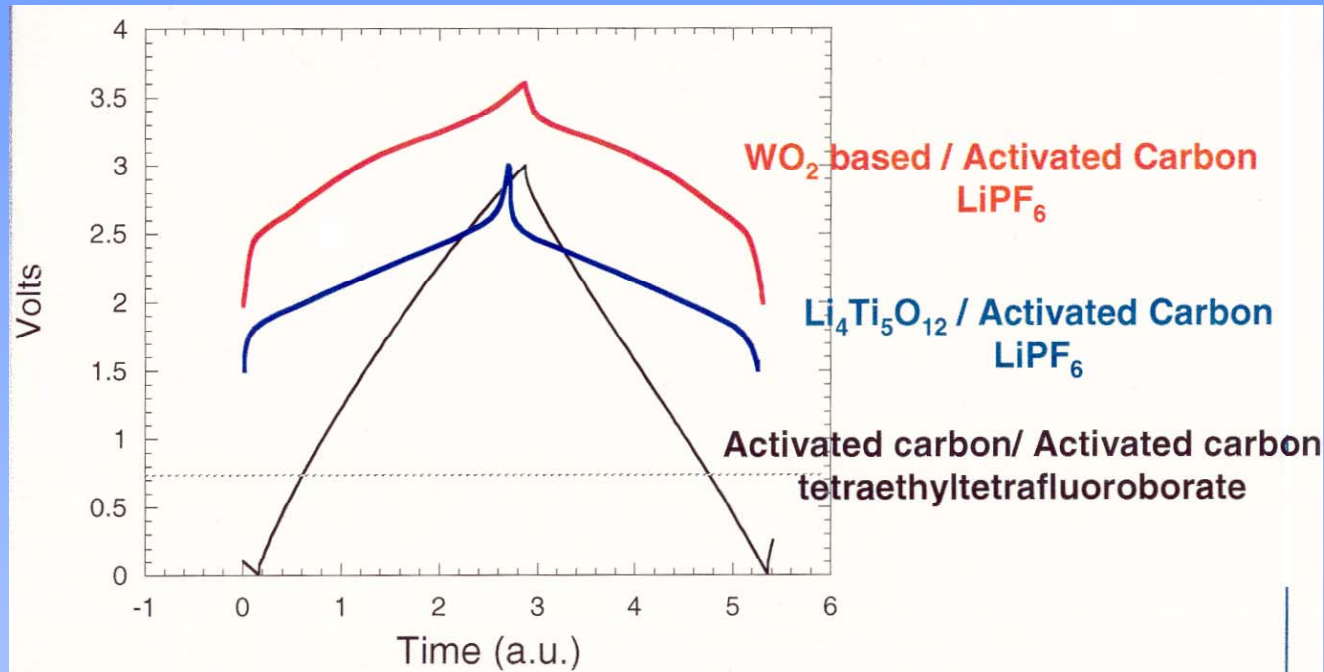
Carbon: $\sim -3\text{V SHE}$

$\text{Li}_4\text{Ti}_5\text{O}_{12}$: -1.5V SHE

WO_2 : -2.3V SHE

Carbonaceous materials are unsafe to operate in high rate applications, because of the risk of Li plating

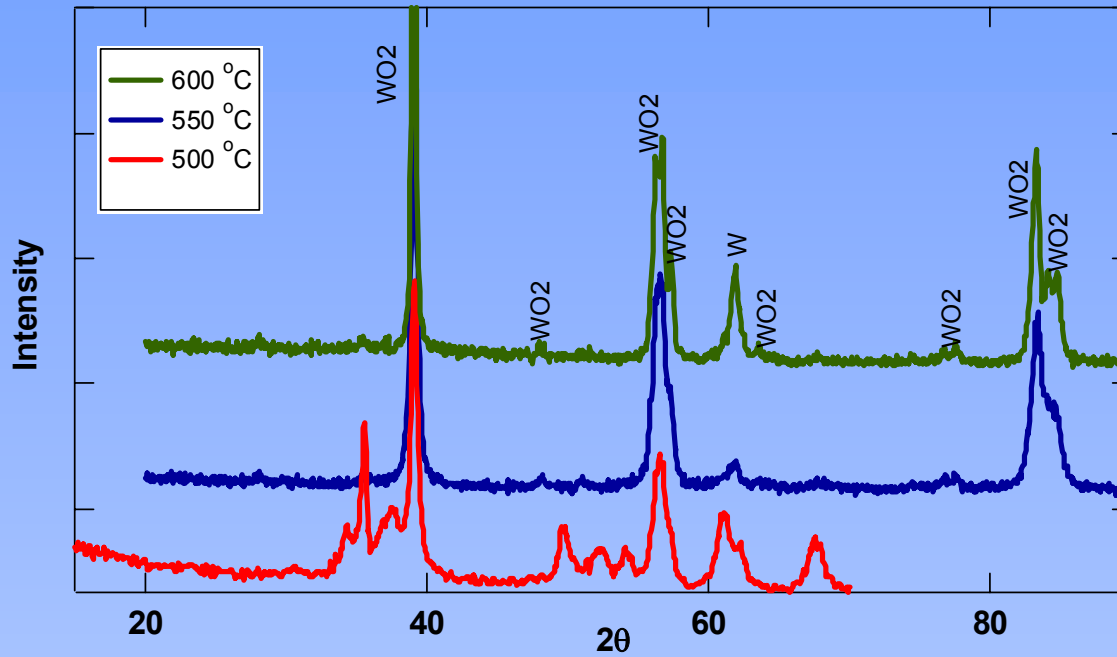
WO_2 has the Highest Output Voltage



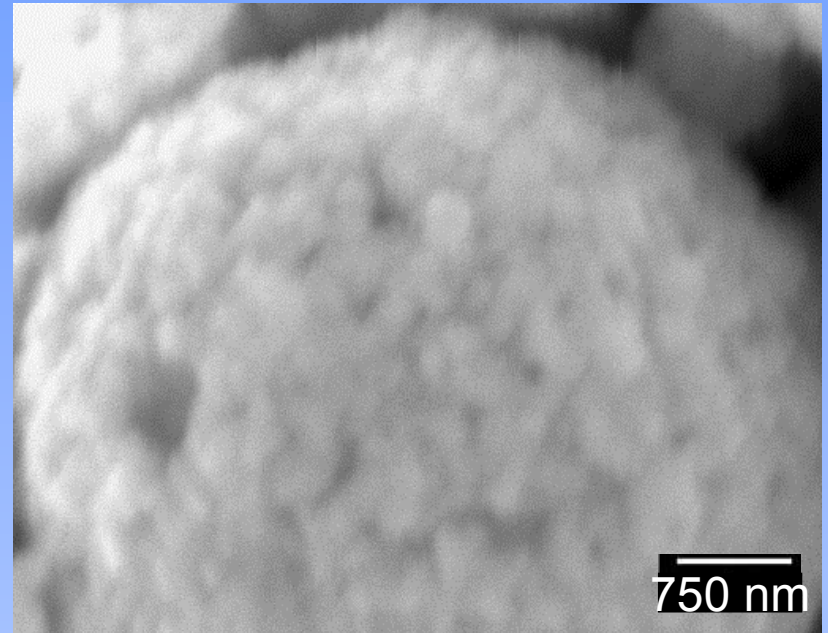
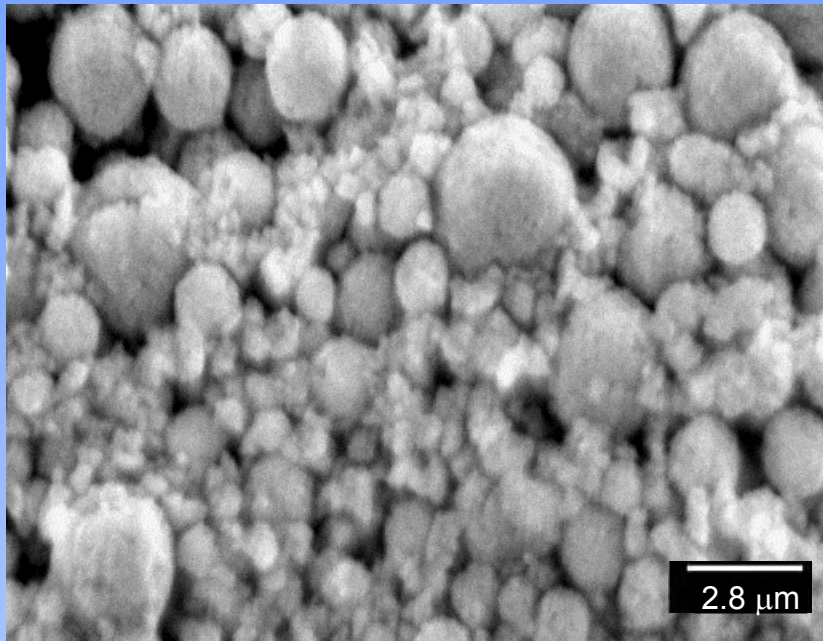
Courtesy Telcordia Technologies

Use of WO_2 anodes will enhance the energy density of asymmetric hybrid cell

Low Temperature Synthesis

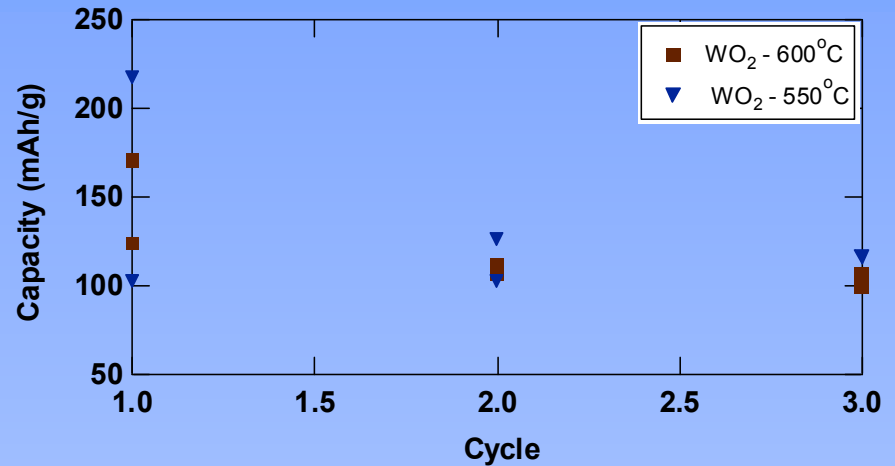
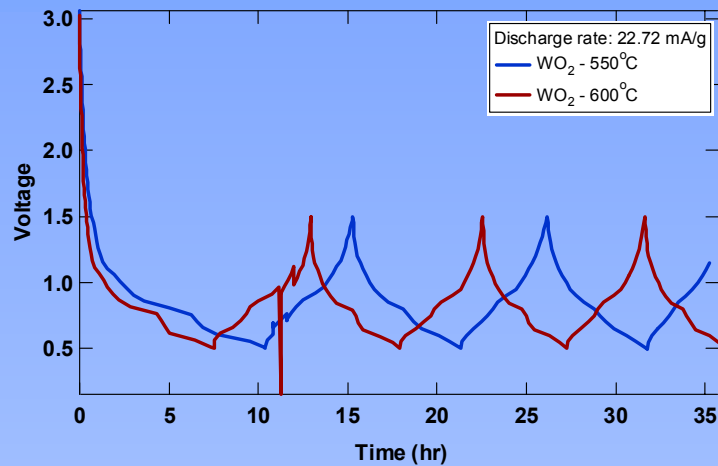


Spherical Particles with Ultrafine Crystallites

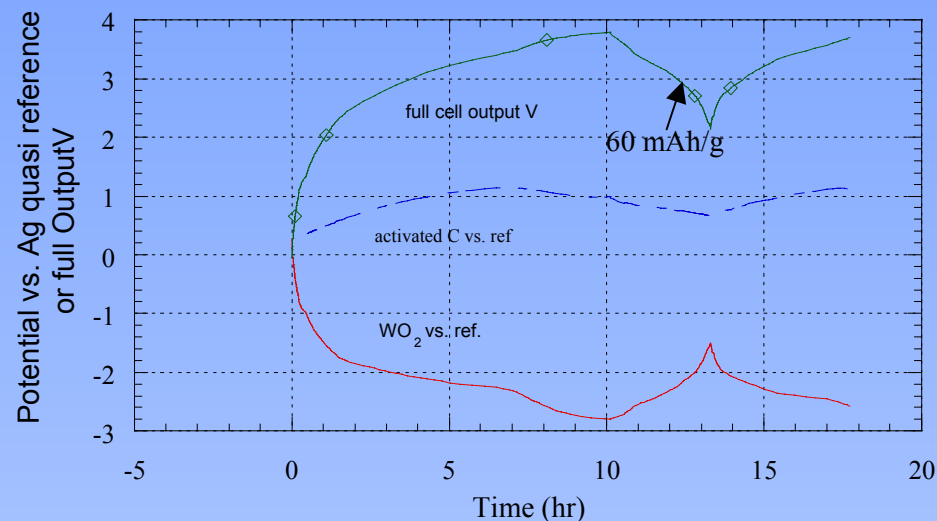
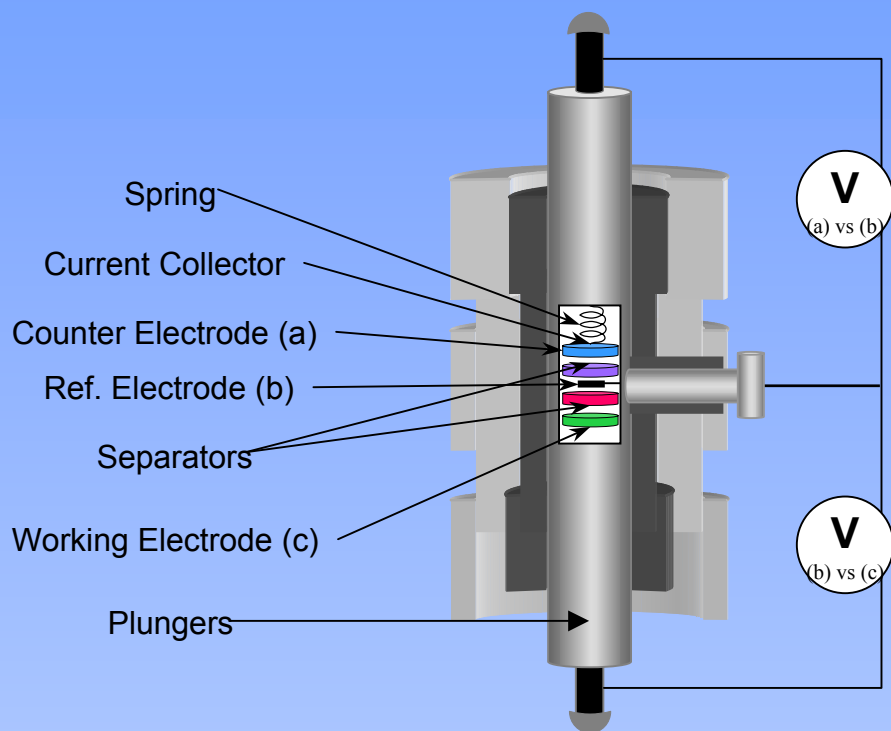


Spherical particles will result in high packing density of electrodes
Surface area = 15 m²/g

Ultrafine WO_2 Powders Are Electrochemically Active



Electrochemical Data in An Asymmetric Hybrid Cell



Program Overview

